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THESIS

RESEARCH REGARDING THE STUDY THROUGH MODELING AND SIMULATION OF THE WORKING UNITS OF SOME WINNING MINING MACHINES

-SUMMARY-

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TABLE OF CONTENTS

The evolution of rock winning machines has recently undergone special developments, especially in terms of the extensive and especially intensive characteristics of the constructive and functional parameters. However, there are still underbeneficiated reserves about the design and manufacture of their working units, especially in terms of durability and adaptability to the wide variety of conditions of the technological environment in which they have to work.

In this sense, classical methods, based on experimental laboratory and field data, as well as theories burdened by simplifying hypotheses often lead to oversizing or incompatibilities that are discovered only after their manufacture.

For these reasons, it is necessary to implement flexible modeling and simulation methods that are easy to adapt to concrete situations for the interactive design and analysis of those products. From this point of view, the topic addressed in the thesis is particularly actual.

The objective pursued in this doctoral thesis is to demonstrate the applicability of modern modeling and simulation methods in the study, design and verification of the working units of winning machines used in the mining industry.

The originality of the paper consists in the fact that, starting from the findings and results presented in the literature and obtained in previous research activities, it managed to implement these theoretical and experimental methods in a coherent system, based on general purpose computer applications, adapted the needs of design and verification of this type of equipment.

As the field of application is particularly wide, we have limited the research to the machines with the widest use and with proven potential for further technological evolution. Both the theoretical developments and the proposed methods of analysis, exemplified on existing machines, are suitable for generalizations and sustainable applications in accordance with the trends of future evolution of these machines.

In the thesis we followed a logical chain from simple to complex, starting from the presentation of the theoretical elements and ending with concrete applications both at the level of each chapter and in the general structure of the paper.

The doctoral thesis is structured in four chapters of content, an introduction and a chapter of conclusions and personal contributions.

Thus, chapter 1 entitled ''CHARACTERISTICS OF MECHANICAL COAL CUTTING'', we analyzed the process of mechanical winning of rocks, with special reference to coal cutting.

We concluded, based on the presented findings that the study of the process of rocks winning by cutting involves establishing correlations between parameters that are specific to the extracted rock, constructive parameters of bits, working unit parameters, chip characteristics and functional parameters of the machine, by combining theoretical

developments. with experimental tests on test rig, and the analysis must be done from simple to complex, from the interaction of a bit with the rock body to the overall interaction of the working unit with the working face .

During the chapter we made illustrative, original graphic-computer models, which represent a preamble for the simulation models that we extended and developed later to detail the aspects related to the specialized extraction machines analyzed.

The second chapter, entitled ''RESEARCH ON THE KINEMATICS AND DYNAMICS OF SINGLE BUCKET EXCAVATORS'', is dedicated to research on the study by modeling and simulation, using computer applications, of single bucket excavators.

The essential feature of these machines, used for excavating and loading ore or rock materials, in mining and construction, is that their performance, such as work space, technological forces, cutting and loading capacity, are closely linked with the structure and operation, kinematics and dynamics of the bucket-boom mechanism.

Based on the theory of manipulators, creatively taken and adapted from the literature, we made a virtual model of the excavation system of an existing excavator, in the SOLIDWORKS application.

By simulation, on this model, we performed the kinematic and dynamic analysis of this system, for a complete excavation cycle, comprising the sequence of the stages of lowering the bucket, cutting, lifting, transporting and unloading the excavated material.

As a result of the simulation, we obtained the spatial trajectory of a tooth on the excavator bucket, we determined the size of the technological volume and the diagrams of variation in time of the speed and acceleration of this characteristic point on three directions.

On the same model, we simulated the dynamics of the excavation system, respectively we determined the power needed to carry out the excavation process in its different stages, taking into account, for each component the related technological, inertial and resistance forces, corresponding to the operating regime.

At the end of the chapter, we performed an analysis of the excavator's bucket loading by calculating the von Mises stress from the beginning of the bucket movement, until the completion of its discharge, taking into account all the forces acting on the bucket.

The working methods used and the results obtained, presented in this chapter are likely to confirm the correctness of the approach by modeling and simulation of the constructive-functional aspects of this type of machine, characterized by a complex structure and kinematics.

Chapter 3, entitled ''SIMULATION AND MODELING OF THE BUCKET WHEEL OPERATING PARAMETERS OF THE EXCAVATOR DURING THE EXCAVATION PROCESS'', includes the results of research conducted on the study of the operation of bucket wheel excavators.

This type of cutting-loading-hauling equipment is widely used in up-to-date open pit lignite mining operations, especially in Europe, both for the extraction, in continuous flow of the coal (lignite) and for the extraction of overburden rock.

Bucket wheel excavators are complex, expensive equipment with high installed power, and their improper operation can lead to financial losses or serious damage, which is why the approach of their study by modern methods, using computer aided tools, is particularly useful.

The most important structural-functional element of the bucket wheel excavator is the so-called load bearing structure, which includes the rotor (bucket wheel), the boom (arm) and the connecting elements to the infrastructure.

For this reason, in this chapter we have addressed in particular the aspects related to the parameters of the excavation regime, with reference to this equipment, systematizing the geometric, kinematic and functional parameters in a logical sequence and interdependence with the efficiency parameters of the excavation process, and namely excavation capacity and energy consumption.

In order to carry out the study, we made a computer graphic model of the rotor and the rotor-boom assembly, in the SOLIDWORKS application, a model that allowed the simulation of the excavation process, obtaining as output the trajectories of the cutting tool and diagrams of variation of metrics that characterize the kinematics and dynamics of the rotor.

Using this model, we developed and applied, for a specific case, a numerical method for calculating the drive power of the excavator's bucket wheel using computer modeling.

By the aforementioned numerical method, we established the correlation between the height of the excavated slice and the swivelling speed of the boom, in order to optimize the driving power of the bucket wheel and increase the energy efficiency of the excavation process, a method that can be applied in practice to increase excavator's performance. and reducing operating costs.

Chapter 4, entitled "RESULTS OF RESEARCH ON THE MODELING AND SIMULATION OF THE WORKING UNITS OF MINING SHEARER-LOADERS", refers to the main winning equipment used in underground coal mines, namely the sherarer-loaders.

In this chapter we have developed an interactive, graphical-numerical method of construction, modeling and simulation of the working units (drums) of mining shearer-loaders based on the realization, in the first phase of a simplified 3D model of the drum on which are built the helical vanes on which the bits are placed.

We have exemplified the proposed method on the working unit of a modern shearer-loader, which is widely used in coal mines, worldwide.

For the modeling and simulation of the helical drum type working unit of this shearer-loader, we used the SOLIDWORKS application, which through its simulation and

visualization modeling facilities proved to be very useful and suitable for this purpose.

Based on the specifications resulting from the drum model made in this analysis, using the CAM component of the SOLIDWORKS application, we materialized, by 3D printing, a physical scale model of the drum. This proves that the study based on modeling and simulation with computer tools can be continued until the computer-aided manufacturing (CAM) phase, with the mention that, if suitable manufacturing equipment is available, prototypes of the systems can be made quickly in order to be assessed in real conditions.

In order to analyze the efficiency of bits placement schemes at an existing or designed working units, we developed a virtual device that allows checking the parameters of bit placement schemes on the drum, which can also be used for geometric and kinematic analysis of the working units of the roadheaders, whose analysis is more difficult to achieve with classical methods, due to their more complex geometry and kinematics.

Using the 3D model of the drum and the bit lacing layout of the bits, we proposed a method of obtaing the chip breakout pattern, in which the chips are represented in 3D, so you can determine the actual volume of each chip and the total volume extracted at a complete rotation of the drum, a method which is an improvement of the classical method of manually constructing the unfolded cutting scheme.

We used the aforementioned application for modeling the drums of some mining shearer-loaders whose design and manufacturing was the subject of older design tasks of the Department of Industrial Mechanical Engineering and Transport of the University of Petroșani which were made with classical graphic and analytical means, which represented a high degree of difficulty and provided limited accuracy in the calculation of parameters and the establishment of technical specifications for manufacturing, especially in the case of helical drums with variable radial-axial pitch.

GENERAL CONCLUSIONS, OWN CONTRIBUTIONS AND RESEARCH DIRECTIONS

CONCLUSIONS

- the study of the process of rock winning by cutting involves establishing correlations between parameters that are specific to the extracted rock, constructive parameters of bits, working unit parameters, chip characteristics and functional parameters of the machine, by combining theoretical developments with experimental tests on test rigs, and the analysis must be made from simple to complex, from the interaction of a bit with the rock mass to the overall interaction between the working unit and the rock mass;

- the essential feature of single bucket excavators, used for excavating and loading ore or rock materials, in mining and construction, is that their performance, such as work space, technological forces, cutting and loading capacity, are closely related to the structure and operation, the kinematics and dynamics of the bucket-boom mechanism, which can be

studied based on the theory of manipulators, creatively adapted for the construction of a virtual model;

- the working methods used and the results obtained, confirm the correctness of the approach by modeling and simulation of the constructive-functional aspects of the excavator with arm and bucket, equipment characterized by a complex structure and kinematics;

- rotor excavators are complex, expensive equipment with high installed power, and their improper operation can lead to financial losses or serious damage, which is why the approach of their study by modern methods, which uses modeling and simulation using computer tools, is special useful;

- the study of the parameters of the excavation regime of bucket wheel excavators requires the systematization of geometric, kinematic and functional parameters in a logical sequence and in interdependence with the efficiency parameters of the excavation process, namely the excavation capacity and energy consumption;

- the problem of ensuring the equidistance between the cutting lines and the location of the bits on the cutting lines and on the edge of the drum vans, is the most difficult to achieve with precision in the classical method of design of the working units of the shearer loaders;

- by simulating on a digital model the working units of the shearer loaders, using the application made and presented, the operation of the respective working unit and of the whole shearer loader can be dynamically visualized, for the analysis of the operating behavior of an existing machine, under given conditions, or to check the functionality of a machine in the design stage;

- the model developed for the simulation of the working units of the shearer loaders can be extended for the geometric-kinematic analysis of the working units of the roadheaders, whose analysis is more difficult to perform with classical methods, due to their more complex geometry and kinematics.

OWN CONTRIBUTIONS

- creation of illustrative, original graphic-computer models, which constitute the starting point for the extended simulation models and later developed for the detailing of the aspects related to the analyzed specialized extraction machines;

- creation of a virtual model of the excavation system of an existing single bucket excavator, in the SOLIDWORKS application;

- performing the kinematic and dynamic analysis, by simulation, on this model, of the mentioned system, for a complete excavation cycle, comprising the sequence of the stages of lowering the bucket, cutting, lifting, transporting and unloading the excavated material;

- establishing, by simulation on the realized model, of the spatial trajectory of a tooth on the excavator’s bucket;

- determining the size of the technological volume and drawing the diagrams of variation in time of the speed and acceleration of a characteristic point on three directions;

- by simulating on the model the dynamics of the excavation system, we determined the power necessary to carry out the excavation process in its different stages, taking into account, for each component part the related technological, inertial and resistance forces, corresponding to the operating regime;

- performing an analysis of the excavator's bucket loading by calculating the von Mises stress from the beginning of the bucket movement until the end of its unloading, taking into account all the forces acting on the bucket;

- creation of a computer graphic model of the bucket wheel and of the bucket wheel-boom assembly, in the SOLIDWORKS application;

- simulation on this model of the operation of the excavation mechanism and determination in this way of the tooth trajectories and of the diagrams of variation of the metrics that characterize the kinematics and dynamics of the bucket wheel;

- elaboration and application, for a concrete case, of a numerical method for calculating the driving power of the bucket wheel, by computer modeling;

- establishing, by the aforementioned numerical method, the correlation between the height of the excavated slice and the swiveling speed of the boom;

- the resulting diagram can be applied in practice to optimize the driving power of the bucket wheel and increase the energy efficiency of the excavation process;

- we developed an interactive, graphical-numerical method of construction, modeling and simulation of the working unit of the shearer-loaders;

- I materialized, by 3D printing, a physical scale model of the drum of a real shearer-loader, which was the object of analysis, based on the export of the specifications resulting from the model, using the CAM component of the SOLIDWORKS application;

- I have developed a virtual device, made with computer means, which allows the verification of the parameters of the schemes of placement of the bits on the working unit of the shearer-loaders, at the existing or designed ones;

- I proposed a method for making the spatial cutting scheme, in which the chips are represented in 3D, so that the actual volume of each chip and the total volume extracted at a complete rotation of the drum can be determined, which is an improvement of the classical method of construction of the unfolded cutting scheme;

- modeling of the working units of some shearer-loaders whose design and realization was initially realized with classical graphical and analytical means, offering a higher precision in the calculation of the parameters and establishing the technical specifications for manufacturing, especially in the case of radially-axial variable pitch helical drums.

FURTHER RESEARCH DIRECTIONS

- the performed research can be continued in order to achieve an integrated test rig-measurement system-recording-computer system, of expert system type, which will perform, based on the measured forces and 3D scanning of the traces of the bits, the determination of the cutting parameters with a single bit, with different geometric parameters (specific shear strength, chip volume), to store the results in a database, from which the computer system to take the data and to realize, interactively, the optimized model of the designed cutting tool, possibly to anticipate the functional parameters of the drum and shearer-loader in real working conditions;

- on the basis of the aforementionned, a sherarer simulator can be made, which will use the databases thus created and provide through virtual or augmented reality a realistic simulation of the operation of the sherarer under given conditions;

- materialization of the prototype of the working unit of the combine through CAM technologies, controlled by the aforementioned modeling-simulation application;

- for single-bucket and single-bucket excavators, the analysis, based on the method presented in the thesis, can be extended to the bucket teeth, taking into account the shear forces based on the characteristics of the excavated material, determined on cutting testing rigs or standard rock mechanics tests, if a system of correlation of standard physical-mechanical properties with those related to rock cutting behavior is developed;

- for bucket wheel excavators, an excavation simulator can be made, through virtual and / or augmented reality, to simulate the excavation process based on the commands from a real control cabin;

- by using the databases on the exploited deposit, and the expert system developed based on the presented models, it is possible to estimate (forecast) the energy consumption for deployment / excavation and the real-time optimization of the excavation and cutting processes can be achieved;

- the application in parallel with or instead of the classical statistical analysis of the variability of the excavation / cutting process of newer methods of dealing with uncertainty, such as soft computing or artificial intelligence, such as FUZZY sets, genetic algorithms and others.